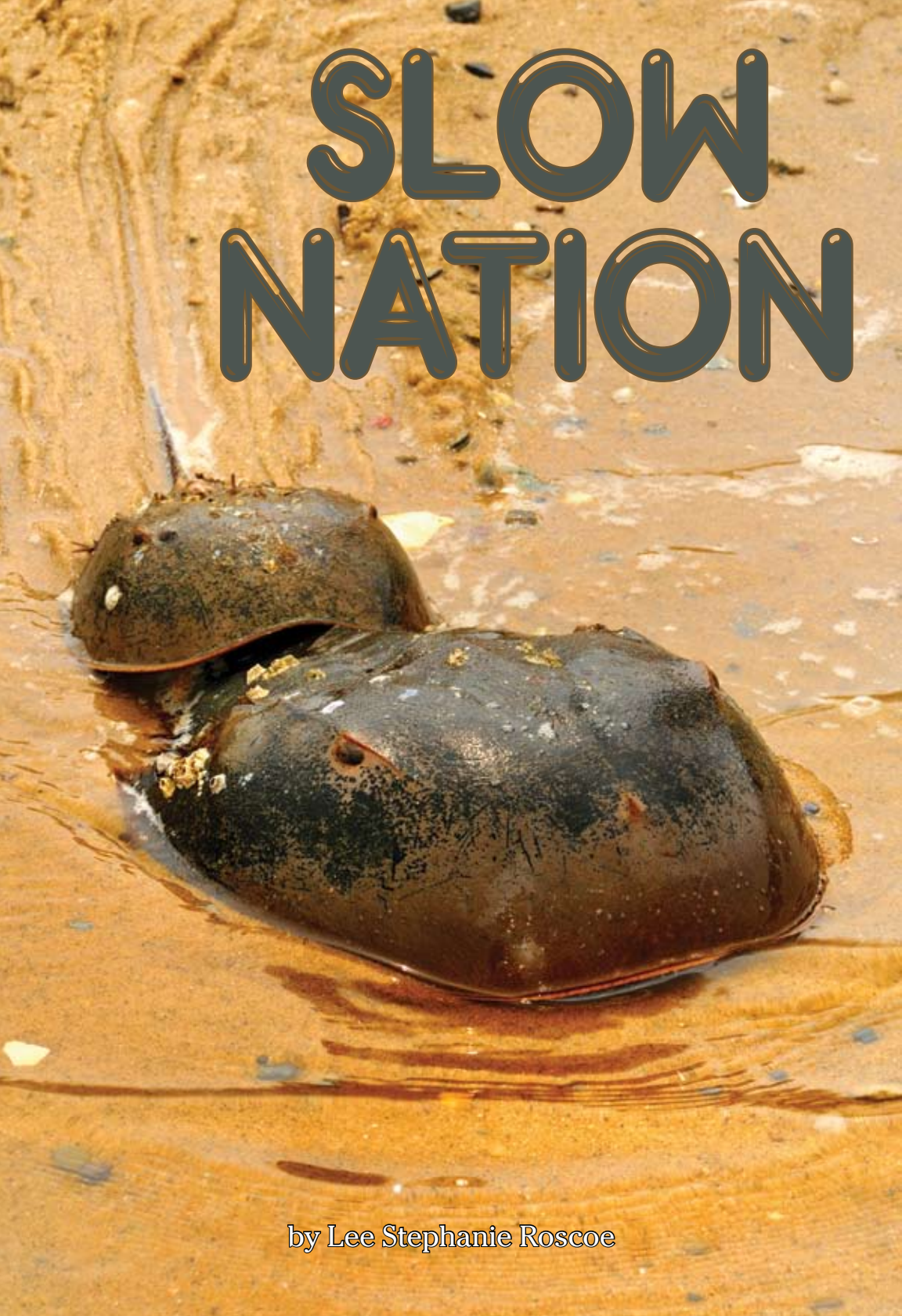
SLOW NATION



by Lee Stephanie Roscoe

aybe it is their duality: a benign nature coupled with a bizarre, almost otherworldly appearance: a crusty Darth Vader helmet enclosing an articulating chaos of jointed, pincer-tipped legs that look dangerous, but are not; hauling a spiny sword of a tail that looks like a dreadful weapon, but is actually harmless.

What is it about the members of Slow Nation that so fascinates us?

Or maybe it is their mystery: When the planet seems filled with the fluid of light and salt, these markers of high tides and spring's flowering seem to arrive magically, sloshing sensually around in the warming waters of our embayments as if drunk on the newly-long days, bent on love when the full moon hangs, champagne-colored, in the night sky.

Or perhaps, if we have seen them on their backs on wave-washed beaches, awkwardly struggling to right themselves, we identify with an endearing klutzy aspect to their character and empathize with their travails. That they can right themselves at all is an evolutionary and gymnastic feat.

The scientific name of these strange organisms, *Limulus polyphemus*, roughly translates as "askew one-eyed giant" or "sideways-looking Cyclops" and was probably derived from a mistaken belief that the animals each had but a single eye. (Polyphemus, son of Poseidon in Greek mythology, was a giant Cyclops who enjoyed snacking on humans; he ate six of Odysseus's men. His name is also given to one of our large moths with an eyespot on each hindwing.) The members of Slow Nation are, of course, horseshoe crabs, captivating creatures of manifold strangeness; aliens from a long lost, ancient Earth that still live among us.

Resembling giants' fingernails digging in the sand, horseshoe crabs congregate to mate at the high tides of late spring and early summer in the ancestral swash waters and intertidal muck near the crest of the water's reach. While some authorities have reported that peak breeding occurs during the new and full moon dates, especially at night, others report no such periodicity, recording them in equivalent numbers at high tides both day and night throughout much of the prime spawning months of May and June. During what might be termed their mating *arribadas*, the females, some as much as a foot wide, are typically observed dragging along one or more clinging males.

Somewhat reminiscent of a nesting turtle, a female horseshoe crab (hsc) intent on reproduction excavates a hand-deep depression in wet sand for her nest. The larger she is, the more eggs she will deposit. A male fertilizes her eggs as she deposits them. Since it is an external fertilization, more than one male may father her young. Biologist Alison Leschen [formerly with the Massachusetts Division of Marine Fisheries (DMF) and now the Reserve Manager at Waquoit Bay National Estuarine Research Reserve] and her colleagues have conducted research on *Limulus* in Pleasant Bay, Cape Cod. She reports that females "return to the breeding beach in waves," to deposit 1-15 golf-ball-sized clutches of eggs per nest in a series of a dozen or more individual nests.

During this reproductive marathon, females may produce up to three multiple-clutch nests per tidal cycle over a period of two or three cycles. The final total amounts to a lot of eggs: "For example," says Leschen, "a large female could lay 8 clutches of 1200 eggs in each of three different nests, return a second time on another tide and do the same, and lay a total of [from] 58,000 to 63,500 eggs." Other researchers have estimated annual egg production as high as 88,000 eggs per large female.

The eggs are soft and gelatinous when first deposited, but quickly harden to resemble BB-sized pepper corns. About five days later, a proper tailless baby crab becomes discernable inside the egg. The tiny crabs hatch in 2-4 weeks and emerge from the sand when liberated by a high tide. Equipped with spines to deter predators, they drift and slosh about as plankton in tidal waters for three weeks, then settle down on the intertidal substrate.

No one knows for sure, but it is estimated that only 10 or fewer of the eggs produced annually by a large female will safely hatch and survive their planktonic and juvenile stages to reach adulthood. Female horseshoes are ready to breed at around nine or ten years of age, while the males (preferring older women) are ready at eight years or so. Both sexes can live until about 20. It is not the crabs themselves, but the elements of the "mobile ecosystem" that they carry around on their backs – including barnacles, limpets, sponges, slipper shells, and algae --that help scientists determine their age. After mating, the adult crabs return from the intertidal gathering areas to the subtidal zones where they will spend most of their lives on the bottom, bulldozing through the benthic landscape in search of food items such as marine worms, algae, and shellfish.

Evolution & Anatomy

There are only four species of horseshoe crabs worldwide, all of which diverged from a common ancestor, *Mesolimulus walchi*, about 150 million years ago. Our species, the American Horseshoe Crab, is the only one that inhabits the Atlantic. It ranges from Maine (where it is scarce) down to Florida, and from there all the way around the Gulf of Mexico, to finally fade out on the northern tip of the Yucatan.

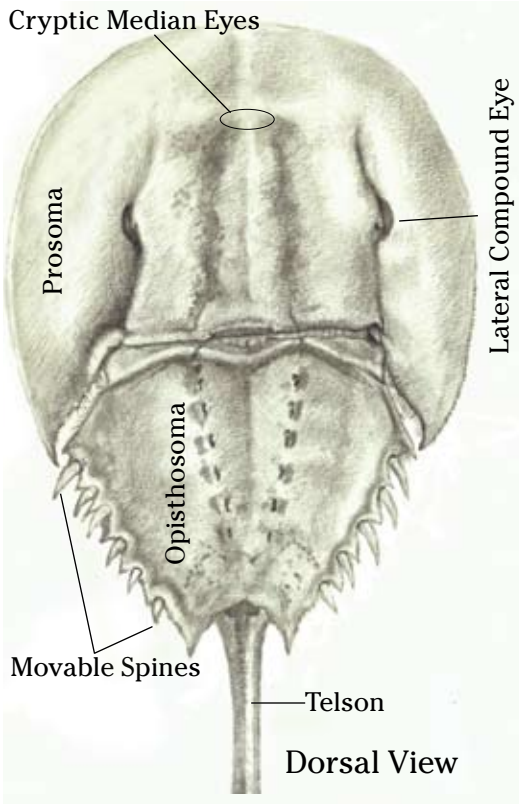
Horseshoe crabs are in the family Limulidae and the phylum Arthropoda, but are placed in their own class, Meristomata. They are not crustaceans and have no relation to the true crabs (which, among other things, lack compound eyes and bear their eyes on stalks). They are thought to be related to the long-extinct trilobites, or perhaps the equally long-extinct sea scorpions (and may even be progenitors, rather than descendants, of that group), but among surviving organisms they are most closely related to the spiders and scorpions. The class name means something like "thigh-mouth" in Greek, which is an appropriate sobriquet since the horseshoe's mouth is located at the center of the legs where the "thighs" all originate. Food is ground up with spines at the bases of the legs as the animal moves along.

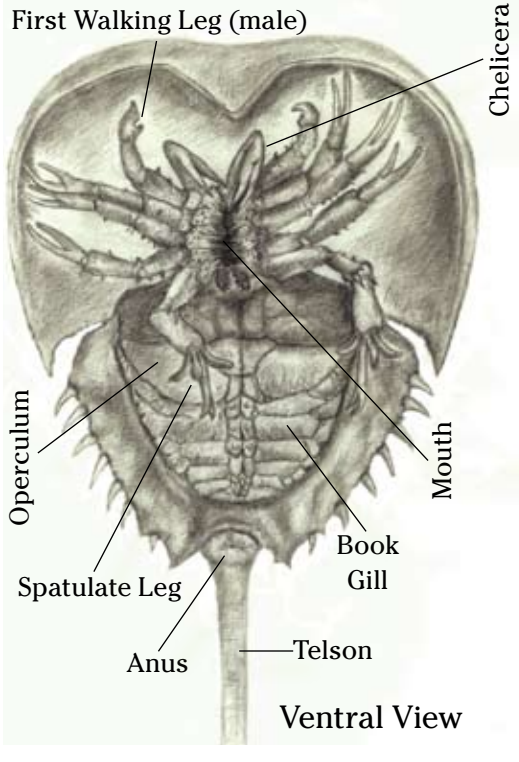
Based on recent fossil discoveries from 445-million-year-old Ordovician sedimentary rocks in Manitoba, recognizable horseshoe crabs have been around for nearly half a billion years. They have swum through epochs, navigated around dividing continents, been pushed about by the rise and fall of mountain ranges, and have spawned on the shores of unnamed seas that came and went long, long ago. They have survived asteroid strikes and numerous worldwide extinctions, seemingly pulling their ocean world ever onward to the present. The oldest known prototype is named *Lunataspis aurora*: "crescent moon shield of the dawn." Two fossils, both of 1.5-inch specimens, have been discovered so far, but it is not yet known if these are tiny, full gown adults, or simply juveniles that would have grown to larger size.

The hsc body is divided into three major sections: the *prosoma*, or carapace, which houses six pairs of walking/feeding appendages and most of the internal organs; the *opisthosoma*, which is hinged to the prosoma and houses the book gills; and the *telson*, or tail spine, which is situated in a hinged pocket at the base of the opisthosoma and equipped with light-sensing organs. The *chelicerae*, outfitted with pincers and used primarily to locate and grasp food, are the first and smallest pair of appendages near the front of the shell (and are a feature shared with spiders and scorpions). They are followed by five pairs of walking legs. On the male, the first pair of these terminate in mitt-like appendages with a single claw, somewhat comparable in look to an old fashioned can-opener. They are used to clasp the female while mating.

On the female, this first pair of legs is the same as the next three pairs on both sexes, ending in pincers similar to those on the ancillary legs of a lobster, and exhibiting the same lack of force when it comes to gripping humans. (Place a junior crab on your hand and there is an almost trusting delicacy to the feel of its legs on your skin.) The fifth pair of legs, larger and longer than the rest, are equipped with collapsible, multiple-leaved "spatula feet" that, like a pair of snowshoes, help the animal to navigate efficiently across soft sand and mud bottoms.

Behind all the legs are six pairs of book gills containing sheaves of page-like respiratory organs that can also be used





Illustrations © Debra Silva

The first pair of walking legs provides an easy way to identify the sex of a horseshoe crab. That of the male, left, is modified to grasp a female during spawning, while that of a female, right, ends in a conventional pincer claw. Collapsible, spatulate tips on last pair of walking legs, below, aid the animals in moving over soft sand and mud bottoms.

Photos © Bill Byrne

for rhythmic propulsion while swimming (especially by the juveniles). The first pair of gills is called the operculum. It serves as a protective cover for the other five pairs, and also houses the opening of the genital pores through which eggs or sperm are released from the body.

The telson – which people often fear is a stinger – is a harmless rudder and "righting organ." A hinge in the body, along with the telson, allows the animal to torque itself into different positions in water and on land, rather like a dancer doing a contraction exercise. When an hsc finds itself upside-down (a common and life-threatening predicament during the breeding season when many are upended by surf) the telson, used in coordination with body contractions and movable spines on the opisthosoma, will often allow it to flip itself back over. Using its legs, jointed body, flapping gills,

Photo © Bill Byrne

"Thigh mouth" is an appropriate name for the horseshoe crab, since the mouth is located at the center of the legs and food is ground up by their action. The chelicerae (paired claws above the mouth) are used primarily to find food and pass it to the mouth. Right, horseshoe crabs must periodically shed their shells in order to grow. This discarded shell shows the opening the crab used to exit the old shell.

and telson, an hsc can swim rightside-up or upside-down, and can burrow into sand to escape predators or survive a stranding. So long as its gills remain moist, a crab can live out of water for days at a time.

Limulus has nine, mostly cryptic eyes. The larger, lateral, compound eyes, each containing about a thousand individual lenses, are the only obvious ones, and are probably the most important for identifying potential mates. These have the largest rods and cones of any known animal, roughly 100 times the size of our own, making the hsc an important subject for researchers studying various aspects of vision. Less easy to see without a microscope is another rudimentary eye behind each lateral one. Then there are two median eyes in the top of the shell, front and center, surrounding one *endoparietal* ("within a cavity") Cyclopean eye. On the underside, just in front of the chelicerae, is yet another pair of eyes which may help the crab remain balanced while swimming, and are also thought to help perceive food items. In addition to all these eyes, the telson is equipped with photoreceptors which may help a partially buried animal discern day from night.

Like all members of their family, horseshoe crabs must periodically shed their entire exoskeletons in order to grow. Young crabs molt very often and usually in summer, while older crabs, if they do so at all, tend to molt in autumn. The chitinous, spiky shells of the juveniles are pliable and more like your fingernail than the much thicker, harder, smoother shells of adult crabs. The older the crabs get, the more slowly they grow, and the intervals between molts lengthen until they finally stop altogether. Dave Smith, *Limulus* biologist par excellence at the USGS, says: "Females are larger than males because they mature one or two years after males of the same cohort. The extra molt or two [allowed by the delayed maturity] allows them to grow larger."

Gifts & Threats

Human interactions with horseshoe crabs have been extremely beneficial to us, but generally detrimental to the crabs. Indigenous and colonial populations collected them by the thousands to fertilize their fields, and by the 1800s, millions of the crabs were being collected and ground up to feed hogs and poultry. As family farms gave way to suburbia and the coast was increasingly developed for vacation homes in the 20th century, exploitation of the crabs for agricultural purposes declined, while disruption, degradation, and outright destruction of their nesting habitat gradually increased.

Photo © Bill Byrne

At the same time, a growing number of scientists began to turn their attention to the hsc as a research subject. Starting in the 1920s, Dr. H. Keffer Hartline, a researcher at the Marine Biological Lab in Woods Hole, began using horseshoe crabs to study vision. That work would eventually lead to a 1967 Nobel Prize for Hartline and two other scientists who discerned how images are received, transmitted, processed, and perceived through the crab's optic system. Much of what we know about our own eyes and the physiology of vision came directly from the study of hsc eyes. That research work continues, and it was recently proven that sight helps the male crabs find mates (as do pheromones). Other subjects of ongoing hsc research include its biological clock, visual detection of movement, ultraviolet light perception, and how vision sensitivity increases or decreases de pending on the intensity of light/time of day.

While the crabs have given us great gifts in terms of understanding the chemistry and physiology of vision, an invaluable property of their blood, discovered in 1956, has literally saved millions of human lives. Horseshoe crabs, as befits creatures of such ancient lineage, are genuine bluebloods: unlike the hemoglobin of our own blood, which employs iron to transport oxygen and is therefore red in color, the *hemolymph* of hsc blood uses copper to transport oxygen, and as a result, appears blue. It was discovered as early as the 1880s that horseshoe crab blood had unusual clotting properties, but it was not until the 1950s that Dr. Frederick Bang, working at the Marine Biological Laboratory at Woods Hole, discovered that it clotted in the presence of certain bacteria.

This discovery led to more directed research, and Bang and his associates soon determined that it was bacterial endotoxin (found in the cellular membranes of the bacteria that cause spinal meningitis, toxic-shock syndrome, gonorrhea, and typhoid, among others) that triggered the reaction, and that the clotting factor itself was a chemical released by certain hsc blood cells (amebocytes). The researchers named this reagent *Limulus* amebocyte lysate, or LAL, and quickly recognized its potential for profitable medical use. They soon developed a process to extract and purify LAL, which was then used to test medicines, vaccines, medical devices, and blood infusions for bacterial contamination. It was so fast and effective for this life-saving purpose that the U.S. Food and Drug Administration accepted it as a standard test for endotoxins in 1983, creating an ever-growing, worldwide demand for the product.

All efforts to artificially replicate LAL in the laboratory have failed, so horseshoe crabs remain the only source of this precious substance. The result has been the development of commercial "extraction and return" procedures that involve the collection of live crabs by hand or dredge, careful transport of the animals to a laboratory, and, following the extraction of approximately 30% of their blood volume with a heart-piercing needle, transport back to the sea for live release in the area where they were collected. Research indicates that blood volume returns to normal in a week or so, although the blood cell count may take two or three months to return to pre-extraction levels.

Studies conducted by LAL manufacturers indicate the entire process results in the fatality of about 3% of the exploited animals, but other researchers have reported mortality rates of 10-15%, and some as high as 30%, depending on how much blood is drawn, body size, and how long the animal is handled. While reporting regulations vary from state to state. Associates of Cape Cod (the Woods Hole-based sole manufacturer of LAL in Massachusetts) must report the names of the fishermen they buy from, the number of horseshoe crabs they purchase, and "the number of crabs received dead or rejected and the number of dead crabs returned to the biomedical fishermen" to the DMF each year.

In areas where crabs are harvested for biomedical purposes, females--preferred for extraction because of their larger size and therefore greater blood volume – appear to be fewer during the spawn. Biologists reported that in Pleasant Bay, after years of intense harvesting of crabs for LAL, the ratio of spawning crabs was nine males to one female. This is pretty unusual according to Dave Smith. "In an

unharvested population," he says, "sex ratio on the beach is expected to be more like two-to-one or three-to-one on average – although you might see a ratio much higher than that on any given high tide. So, nine-to-one is high, and indicative of female-biased harvest."

Because horseshoe crabs include shellfish in their diet, shellfishermen long regarded them as competitive enemies.

It is almost certain that habitat destruction has also played a part in the decline, and some biologists think this may be the greatest impediment to recovery. Navigational dredging through sea-bottom sediments to keep channels open disrupts the benthic habitat, while in-shore, the building of sea walls, piers, wharves, and jetties; "beach nourishment" projects (a 2009 thesis reported 45 beach fill projects on Cape Cod alone in a 5 year period);

Otherworldly Applications

The horseshoe crab's ancient proteins and enzymes continue to provide useful agents of use to people, offering a compelling example of why allowing the extinction of any species has the potential to deprive future generations of as-yet-unimagined, lifesaving discoveries. The chitin of which the hsc shell is composed is being developed for use in sutures and burn dressings. Elements in hsc blood (in addition to LAL) are being investigated to detect viruses, parasites, and fungi, as well as bacteria. NASA is experimenting with a portable, hand-held device not much larger than a cell phone that uses elements of hsc blood to test swabs from spacecraft for contamination from earth, and potentially to detect alien microbes contaminating spacecraft that return to earth. Ironically, one of Earth's oldest and most primitive species may, as NASA's planetary protection officer hopes, "protect life on other planets in our solar system," from the contaminating activities of one of its youngest and most intelligent species.

A 2006 DMF news release reported: "Several Massachusetts towns offered a bounty of three cents on the tail of a horseshoe crab. In the early 1960s, the Town of Chatham paid $1,500 in total bounty on crab tails, which at three cents each equals 50,000 horseshoe crabs. A review of towns' annual reports suggests that half-a-million crabs or more were killed annually as part of local shellfish predator control programs."

During the 1990s, crabs became extremely popular as a bait to tempt whelks (conch) and American eels (themselves no longer plenteous) into traps. Millions were harvested for this purpose up and down the East Coast, reaching a peak of 6 million (more than 2,500 tons) taken in 1997. This commercial bait harvest was almost certainly the primary cause of their precipitous decline in Delaware Bay (and probably elsewhere) during the past two decades, although beach fill projects and shoreline alterations that damage or destroy spawning habitat are also undoubtedly implicated. Regardless, the decline became so obvious that bird conservationists, LAL manufacturers, and ordinary beachgoers began to raise alarm and demand better hsc conservation.

and even beach cleaning/manicuring operations interfere with breeding/egg development and kill animals outright. As DMF's Vin Malkoski says, "It is pretty disconcerting to be doing a spawning survey and have a town tractor come by, driving over and sweeping up the wrack line where the crabs are laying their eggs."

Other man-made deterrents to continued *Limulus* population abundance include the usual pollutants – hydrocarbons, fertilizers, pesticides, heavy metals, and the like – that wash down the streets of America and eventually into the ocean. Because they won't mate in the murky, high seas of stormy weather, it seems likely that anthropogenic climate change – with its weather extremes, rising waters, and effect on ocean salinity – could also add to their travails.

Of course, sidelong-glance Cyclops also has its own wild predators and natural obstacles to survival. Birds and fishes gobble them up as eggs and young. Sharks and sea turtles chop up and consume adults. Seagulls keep a continual watch and attack any upended crabs they can reach. (The crabs are not incapable of at least one form of revenge, however: many contain encysted, parasitic flatworms

Photo © Bill Byrne

Biologists have identitifed at least 11 species of shorebirds that rely in part on horseshoe crab eggs to fuel their northward migrations to breeding grounds in the spring, an important reason to maintain the crabs in abundance.

that will hatch and mature in a gull's digestive tract!)

Alarm & Conservation

Starting in the late 1980s, as beach goers noticed the once-abundant living cobblestones no more bumbling up to their nude feet on the beach, concern for the species began to swell. Conservationists realized that, at least in some parts of its range, the hsc is a keystone species, the lintel at the top of an ecological structure, which, when destroyed, causes a cascade of devastation that encompasses many other species. In the case of the hsc, it had long been known that at least 11 species of migratory birds relied on crab eggs as a crucial energy source during their spring journeys to northern breeding grounds; that hsc eggs in the sand provide an important food source for millions of resident and transitory shorebirds throughout the crab breeding and incubation period. The more crabs there are churning up the sand, simultaneously digging up previously deposited eggs as they work to bury fresh ones, the more eggs are exposed to the varied lengths of beaks which otherwise could not probe to the level where hsc eggs are deposited.

Coinciding with the rapid decline in hsc numbers in Delaware Bay due to overfishing and other human activities, researchers reported that several species of shorebirds also began to decline in numbers. No species exhibited a more alarming decline than the Red Knot, *Calidris canutus rufa*, a shorebird that feeds almost exclusively on horseshoe crab eggs to refuel during its marathon migration of over 9,000 miles from Tierra del Fuego to the Arctic. As hsc numbers evaporated in the 1990s, the Red Knot population declined by some 70 percent, falling from 100,000 birds to about 15,000. When the crabs had been abundant, hsc eggs were recorded at 40,000-100,000 per square meter of beach. Following the crash, those figures dropped to about 1,500 eggs per square meter and Red Knots went from gaining 9 grams of weight per day to only 2 grams. The link was unmistakable.

As of January, 2012, the Red Knot is under consideration for listing by the USFWS under the 1973 U.S. Endangered Species Act. (Monomoy NWR and other

areas on the Cape are under review as critical habitat for the species.) While hsc egg production in Massachusetts may not be enough to make it a keystone species here as it is around Delaware Bay and the Cape May peninsula, it likely was historically when the "wahquoits" (as the indigenous locals called Red Knots) inhabited Barnstable county in the many thousands in the 19th century, coinciding with copious crabs and unaltered beach habitats.

As concern for the hsc and its resource-deprived predators was raised by conservationists and the LAL industry itself, the agencies responsible for the conservation and regulation of our natural resources responded. The Atlantic States Marine Fisheries Commission (ASMFC) determined *Limulus* was in trouble in the 1990s, and put together a paper outlining its concerns and a proposed management plan in 1998.

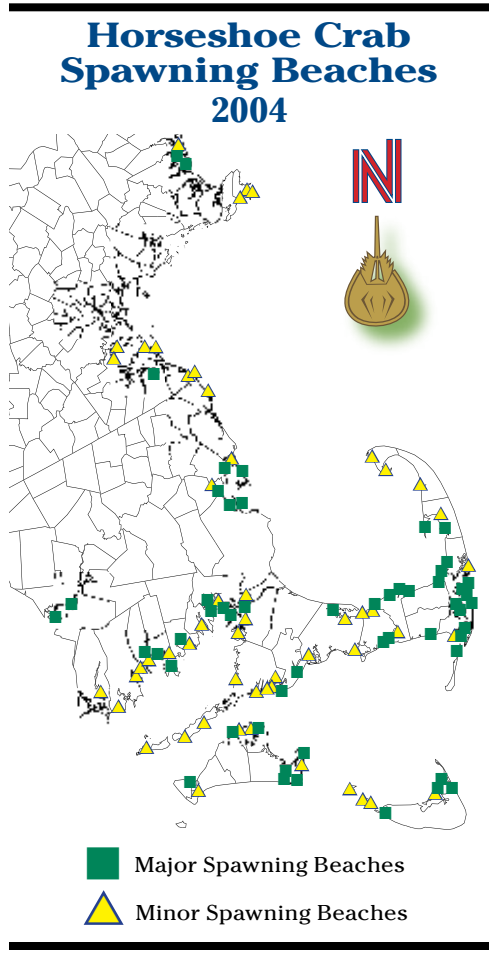
Our own DMF initiated state regulations to conserve *Limulus* in 1999, and its personnel sat down together with assorted scientists from other states and institutions such as URI, Cornell University, the United States Geological Survey (USGS), and many more to develop a new protocol for surveying spawning crabs by coordinated volunteers working under professional biologists. The resulting data would be used to supplement other prior and subsequent research, formal and informal alike, as well as trawl data.

Horseshoe crab nursery sites in the Commonwealth occur from the north shore to the south shore, from Massachusetts Bay to Cape Cod Bay, from Buzzards Bay to Nantucket Sound and the Vineyard. Currently monitored areas include sites in Pleasant Bay (Chatam), Wellfleet Bay, Waquoit Bay, and Monomoy NWR, as well as some in Barnstable Bay, Buzzards Bay, Pleasant Bay (Duxbury), Westport Harbor, Nantucket, and Martha's Vineyard.

In 2010, 21 beaches in Massachusetts were surveyed "by over 250 volunteers and staff from government agencies, environmental organizations, and local service groups." Data from these surveys (as well as those from harvesters and other studies) go through DMF's Vin Malkoski and have not been collated as of this writing. Malkoski says, "We had some problems in 2011 as some groups lost support/funding and others seem to be experiencing volunteer fatigue. [We] don't know how 2012 is going to go."

Other Research

Getting a solid handle on hsc population numbers and trends is obviously difficult, but more formal studies to determine such things as hsc habitat use and migration patterns are yielding interesting discoveries. For instance, it now appears that horseshoe crab populations are locally discrete, and that their members mate, breed, and overwinter in relatively small areas. If this theory holds up, their attachment to a singular place makes local hsc populations especially vulnerable, since new, incoming crabs will not readily replace extirpated populations. It also means that local populations may



be genetically distinct and limited to only one or a few specific spawning sites. Both factors may make them more vulnerable to extirpation.

Dr. Mary-Jane James-Pirri of the University of Rhode Island, assisted by the U.S. Fish & Wildlife Service, tracked the crabs in Cape Cod's Pleasant Bay from 2008 to 2010 using both acoustical and static (non-transmitting) tags, showed that the crabs migrate to local sub-tidal areas after spawning, and then go to over-winter in waters not much more than 30 meters down. Journeys to the continental shelf may be limited or non-existent. She writes that "Isotopic signatures of horseshoe crabs from embayments within Pleasant Bay… Stage Harbor… and Barnstable Harbor… were found to be significantly distinct, suggesting that crabs remain within localized areas long enough to acquire the isotopic signature of the embayment." She has also noted that "Genetic population subdivision over a relatively small geographic area has been documented for horseshoe crab populations in the mid-Atlantic [coast]."

Katherine Terkanian and her cohort, Sarah Martinez, both Master's candidates at the University of Massachusetts who labor out of Massachusetts Audubon's Wellfleet Bay office, are continuing the work. Terkanian asks: "Are Massachusetts horseshoe crabs a singular population, or are they comprised of sub-populations around the coast?" She is conducting DNA studies on the crabs, mostly those from populations on the Cape, but has yet to tabulate and analyze the accumulating data.

Martinez asks: "Where do the horseshoe crabs go to after spawning? How far out do they go? How deep? Are spawning groups limited to very local areas for breeding, and over-wintering?" Working on a joint project with DMF, she is assessing populations around Wellfleet Harbor, Nauset Estuary, Stage Harbor, and Monomoy, Chatham. She has attached acoustical telemetry tags to 75 crabs to see if they migrate out to Nantucket, Monomoy, or further offshore. Each receiver velcroed and glued onto an animal's shell sends a distinctive signal, which is in turn picked up by 22 "Thermos-sized" receivers "moored in cement tubs," then downloaded to the researchers' laptops.

The acoustical transmissions have not yet been fully tabulated, but based on preliminary findings, Malkoski is not afraid to say that the data indicates that, "Crabs tagged on spawning beaches in enclosed embayments tended to have strong site fidelity, while those from more open areas tended to roam around more."

Other methods of getting data include trawls. A recent DMF report states: "Approximately 100 tows are made in five bio-geographic areas, following a stratified random sampling design, with 22 total strata." Malkoski notes that hauling some of the tagged crabs in the late fall, he and his colleagues have so far found that while a few are dragged up from deeper waters by commercial fishermen, most of their retrieved crabs were hunkered

Horseshoe crab researcher Katherine Terkanian and colleague Nate Bent survey for breeding crabs on a Cape Cod beach.

Photo © Bill Byrne

Photo © Katherine Terkanian

Report Tagged Horseshoes!

Researchers use several different kinds of tags to mark and track horseshoe crabs. There are two basic varieties: active tags which transmit acoustic and/or electronic signals (on top of female, above), and passive, non-transmitting button tags (on side of female, plus close-up) or spaghetti tags which come in various shapes and colors and typically include a unique tag number and a USFWS phone number to call if the crab is found. As with bird bands, the idea is to document the location of individual animals over months and years, dead or alive, and then to analyze the ever-accumulating data to determine movement/migration patterns, longevity, and other information that can help direct management efforts. (So far, most crabs appear to be quite prudent in the distances they travel, but there are exceptions such as one that was tagged in Wellfleet in 1998 and ended up in Narragansett Bay in 2007. If you find a tagged crab, record the color and number of the tag, and call 1-888-LIMULUS (USFWS) to report it. You may receive a pewter horseshoe crab pin for your efforts.

down closer to shore (as expected). In general, trawl catch data shows a continuing decrease in hsc numbers, but because the trawl cannot operate in shallow, inshore waters where the crabs may concentrate, significant numbers may be missed.

"There is a great deal about crab populations which remains unknown," Terkanian says. "It may be colder waters produce smaller animals, warmer waters, larger. For instance, crabs in Cape Cod Bay are smaller than those in the Sound, and… in Georgia the crabs are comparatively much larger than here." Why might size matter? "Larger females carry more eggs," she says. "Larger females have greater blood volume." These may be factors determining population numbers and recruitment. "I once saw many, many males clustered around a rubber tire left on the beach," she reports. "Perhaps the largeness of the round, dark tire, like a bigger size of *Limulus* female, might attract more mates!"

A Restoration Response

While the horseshoe crab may not be able to change much, humans in their relationship to it can and have. With an as yet incomplete understanding of crab abundance and recruitment -- and some anecdotal accounts disturbingly suggesting that populations are below

Mature crabs that no longer shed their shells on an annual basis often accumulate large numbers of hitchhikers. This one is hosting a profusion of slipper shells.

Photo © Bill Byrne

90% of what they used to be and might disappear completely -- it is vital that we must. Shellfishermen now realize the crab is a friend that eats clam worms, and even more importantly, turns over and aerates bottom sediments, allowing more organisms such as clam spat to grow. Rumors of illegal collection abound, but most shellfish harvesters want to cooperate.

"There are so many stakeholders," Terkanian says. "Sometimes the harvesters think the biologists are trying to harm their livelihood. We're not. We want to do the science for the sake of all concerned. There are so many uses of the crabs. We want to protect them for their own sake, and the sake of the ecological niche they inhabit. We want to understand them to conserve them as a resource for humans."

The collection of crabs for all uses is down. A DMF report states "In 1999, 151 fishermen reported harvesting 545,715 horseshoe crabs for bait and for biomedical use." In 2010: 54,782. (No one knows if this is because of stricter regulations or diminished stocks, but the limit set on take is now 165,000 crabs; three times higher than what is being landed.) There is now strong pressure to keep hsc conservation a priority, however, and it is supported by government agencies such as DMF and the USFWS, as well as non-government entities such as the Massachusetts Audubon Society and the Horseshoe Crab Conservation Association on Cape Cod. DMF has a difficult balancing act between conserving species and allowing human use of the resource. Since 1999 it has received high marks for its efforts at conservation.

DMF continues to issue stringent regulations which protect *Limulus* during its critical spawning period, including complete closure to harvest all over the state during the new and full moon periods of May and June. When harvest is permitted, there is a take limit of 400-600 animals, and a size limit that protects animals less than 7" across the prosoma. A suggestion sometimes offered at public hearings is to set even larger width restrictions to limit the take of females. Surveys of juvenile crabs to determine their mortality levels are also under consideration. Mass Audubon's Bob Prescott suggests: "We need regional horseshoe crab spawning sanctuaries. We need regulations that will allow the hsc population to return to pre-harvesting levels. It isn't about sustainability; it needs to be about rebuilding the stocks."

Most strikingly, in places where harvest has been limited throughout the local range, there is some evidence of recovery. By current ASMFC assessments, numbers are still down in New York and New England, but increasing in the Southeast and Delaware Bay where closures have been strict. However, in those areas other factors must also be taken into account. These would include warmer water temperatures allowing for more frequent matings from larger, more productive females, and also habitat availability/protection.

Two key federal entities involved in Massachusetts are the Cape Cod National Seashore and Monomoy National Wildlife Refuge. Since 2000, they prohibit any collection within their boundaries (which extend a ¼ mile out from their shores). The National Seashore was particularly

For more information:

www.ceoe.udel.edu/horseshoecrab

PBS's "Crash, A Tale of Two Species" a film by Alison Argo: ***www.pbs.org/wnet/nature/episodes/crash-a-tale-of-two-species/introduction/592/***

And for a great little book on the subject:

Extraordinary Horseshoe Crabs by Julie Dunlap

proactive, and notes that its harvest closure, "…was initially opposed by the State of Massachusetts, which contended that the National Park Service usurped state authority to manage the harvest of fish and shellfish. It was subsequently determined that the closure was within NPS [National Park Service] authority because horseshoe crabs are not classified by the state as either fish or shellfish." A survey in 2001 showed the highest densities and largest crabs on Cape Cod were spawning on Monomoy NWR, and ratios of females to males are higher than on the mainland. In 2011, "Approximately 598 horseshoe crabs were tagged on Morris Island and on North and South Monomoy Islands," and reports of these animals in the years to come may prove useful in assessing survival factors.

The jury is still out, but it well may be that the complete closure to harvest on Monomoy has helped the crabs recoup beyond those on the mainland. But then again, Monomoy has always had big hsc numbers: Prior to regulations and closures, the NWR yielded the highest harvest of horseshoe crabs anywhere in Massachusetts in 1999. In the 1950s, the crabs abounded there in the thousands; the refuge manager commented in an official report that it was "too bad we can't find an economic use for them."

Prescott mentions that around his turf at Wellfleet Bay, numbers have plummeted since the 1980s, but he is hopeful that nature may create new opportunities for recovery: "A blizzard created a break and wash-over in a beach at Pleasant Bay which created a whole new area for horseshoe crabs [to spawn], as well as for least terns, piping plovers and diamondback terrapins. That's how barrier beach ecology works."

With its slow, bumbling nature, leaving its shell like an ancient tribal mask on the sands, delighting children with its "sword," the horseshoe crab defines coastal areas in early summer as it churns itself over, moving into the near surf, in areas redolent of sea and algae and wrack, while gulls, terns, and shorebirds stoop and cry overhead. With protection and continued research, and a determination on our part to conserve them for both selfish and altruistic reasons, Slow Nation should remain with us for generations to come. In fact, if geologic history offers any guidance, horseshoe crabs will likely remain long after we have gone.

Lee S. Roscoe is a playwright and freelance writer. Her articles appear frequently in the Barnstable Patriot*, and her feature on the Sandwich Hatchery centennial will appear in* Cape Cod *magazine this spring. She occasionally gives walks through* ***www.capecodwalks.net*** *and is the author of the book* **Dreaming Monomoy's Past, Walking Its Present**. *Our readers may remember her previous articles on such diverse subjects as didemnids, tiger beetles, and fireflies.*

Photo © Bill Byrne

Division of Fisheries & Wildlife
Field Headquarters
Westborough, MA 01581

A pair of mating horseshoe crabs, the male clinging to the larger female, nest on a beach at high tide in late spring. These ancient creatures, unrelated to the true crabs, come ashore at many of our beaches in May and June to lay their eggs. The female digs a hole and deposits golfball-size clumps of eggs, which the male fertilizes externally. She may lay tens of thousands of eggs in a season, but it is estimated that fewer than 10 will survive to adulthood. The eggs are eaten by a great variety of shorebirds, including some that are almost wholly dependent on this seasonal, high calorie food supply to provide them with the energy they need to complete their spring migration and arrive on the breeding grounds with enough reserves to survive the rigors of egg production and chick rearing. Significant reductions in horseshoe crab populations, which support both commercial bait fishermen and medical products extractors, have become a great concern of conservationists.

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